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A contemporary series of patients undergoing open debridement for necrotizing pancreatitis

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KEYWORDS:
Pancreatic diseases;
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Debridement;
Minimally invasive surgical procedures;
Sensitivity and specificity

Abstract

BACKGROUND: For patients with acute pancreatitis complicated by infected necrosis, minimally invasive techniques have taken hold without substantial comparison with open surgery. We present a contemporary series of open necrosectomies as a benchmark for newer techniques.

METHODS: Using a prospective database, we retrospectively identified consecutive patients undergoing debridement for necrotizing pancreatitis (2006 to 2009). The primary endpoint was in-hospital mortality.

RESULTS: Sixty-eight patients underwent debridement for pancreatic/peripancreatic necrosis. In-hospital mortality was 8.8% (n = 6). Infection (n = 43, 63%) and failure-to-thrive (n = 13, 19%) comprised the most common indications for necrosectomy. The false negative rate (FNR) for infection of percutaneous aspirate was 20.0%. Older age (P = .02), Acute Physiology and Chronic Health Evaluation II score upon admission (P = .03) or preoperatively (P < .01), preoperative intensive care unit admission (P = .01), and postoperative organ failure (P = .03) were associated with mortality.

CONCLUSIONS: Open debridement for necrotizing pancreatitis results in a low mortality, providing a useful comparator for other interventions. Given the high FNR of percutaneous aspirate, debridement should not be predicated on proven infection.
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Acute pancreatitis afflicts over 200,000 people annually in the United States and its incidence appears to be increasing.[1] Approximately 20% of patients have disease complicated by necrosis of the pancreatic parenchyma or peripancreatic tissues[2] and 30% of those patients develop infected necrosis.[3] Without some form of intervention—surgical, endoscopic, or percutaneous radiologically guided—infected necrosis carries an extremely poor prognosis.[4,5] The indications, timing, and techniques for intervention have recently undergone considerable evolution.[6] In the past, earlier debridement, including for sterile necrosis, was commonplace. Currently, most practitioners

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delay intervention until 4 weeks after the onset of disease and the only clear indication for intervention is necrotizing pancreatitis complicated by proven infected necrosis.[7] In addition to an evolution in indications for and timing of intervention, the interventional approach has shifted away from open surgical debridement and toward minimally invasive methods such as transgastric endoscopic debridement, percutaneous drainage, video-assisted retroperitoneal debridement (VARD), and laparoscopic necrosectomy, alone or in combination.

Although there may be advantages to these minimally invasive approaches, we have long favored open surgical debridement at our institution and have previously shown that it can be accomplished with low mortality, acceptable morbidity, and relatively short hospital stays.[8] Recent evolution in critical care as well as the timing and indications of surgical debridement may have improved the clinical outcomes of open surgical debridement for patients with acute pancreatitis, rendering older reports obsolete. In an environment in which minimally invasive techniques are increasingly taking hold with little direct comparison with open surgery, we present a contemporary series of open necrosectomies. These results may serve as a basis for comparison with newer techniques.

Patients and Methods

Data source

The Massachusetts General Hospital Division of General Surgery maintains a prospective pancreatic surgery database. With the approval of our Institutional Review Board, we performed a retrospective review of all patients undergoing pancreatic debridement for necrotizing pancreatitis over a 4-year period (January 2006 to December 2009), which covers all patients from our last published report to initiation of this study.[8] Because of increasing adoption of a "step-up" approach since the beginning of 2010, this time period provides the most contemporary data that could still be considered representative of a strategy based on open necrosectomy.[9]

Variables

We collected patients' demographic and clinical characteristics including age, sex, admission source, cause of pancreatitis, history of immunosuppression, history of diabetes, Acute Physiology and Chronic Health Evaluation II (APACHE-II) score at presentation and at the time of debridement, need for intensive care unit (ICU) admission, presence of organ failure, and computed tomography (CT) findings. In the event of missing input parameters for the APACHE-II score, the most physiologically stable clinical values were employed. We defined organ failure as circulatory failure (systolic blood pressure <90 mm Hg or need for vasopressors), pulmonary insufficiency (PaO_2 <60 mm Hg), or renal failure (creatinine >2 mg/dL after rehydration), in accordance with the Atlanta classification of acute pancreatitis.[10] When CT images were available, we used the Balthazar criteria to grade the severity of acute pancreatitis from A (normal pancreas) to E (2 or more fluid collections and/or retroperitoneal air).[11] Additionally, the Balthazar grade was combined with the degree of necrosis to compute the acute pancreatitis CT severity index, which ranges from 0 (least severe) to 10 (most severe).[11]

We also collected treatment-related variables including the indication for debridement, time from onset of pancreatitis to debridement, preoperative use of percutaneous radiologically guided drainage catheters, and use of parenteral nutrition. Infected necrosis was diagnosed preoperatively in 1 of the 2 ways: (1) positive microbiologic cultures of the pancreatic or peripancreatic necrosis from fine-needle aspirate or percutaneous drain fluid or (2) air in the area of pancreatic necrosis visualized by CT imaging. Operative cultures were used as the gold standard for purposes of comparison. Failure to thrive was determined by a combination of malaise, nausea, persistent abdominal pain, and weight loss, which did not improve with nonoperative management. The surgical technique involved either a transmesocolic, anterior (through the gastrocolic omentum), or retroperitoneal approach to the pancreas, debridement of all the necrotic tissue and associated debris, external drainage with closed suction drains, and, in most cases, closed packing with stuffed penrose drains.[12] We recorded the exact approach used, operative time, and intraoperative blood transfusion. We defined "early" (vs "late") operative intervention as surgical debridement sooner than 28 days from the onset of symptoms.

Statistical analysis

The primary endpoint was in-hospital mortality. Secondary endpoints included new postoperative organ failure, reintervention (reoperation or percutaneous radiologically guided drain placement), wound infection, and pancreatic fistula. Pancreatic fistula was defined as continuous output from a drain placed in the pancreatic bed. The interval to spontaneous fistula closure was defined as the number of days from drain placement to drain removal not followed by fistula recurrence. We used chi-square tests or Fisher's exact tests to assess categorical variables and t tests or Mann–Whitney U tests to assess continuous variables. Patients with missing data were excluded from each respective analysis. We set the alpha level of statistical significance at .05. All data were analyzed using SAS version 9.3 (SAS, Cary, NC).

Results

Preoperative characteristics

We identified 68 consecutive patients who underwent open surgical debridement for necrotizing pancreatitis.

Table 1 Baseline characteristics of 68 patients before debridement for necrotizing pancreatitis

Variable	Overall cohort (n = 68)
Male	48 (70.6)
Age at onset (years)	54.2 ± 1.7
Etiology	
Alcohol	26 (38.2)
Gallstones	19 (27.9)
Hypertriglyceridemia	5 (7.3)
Ischemia	4 (5.9)
ERCP	3 (4.4)
Postbiopsy	2 (2.9)
Other/unknown	9 (13.2)
Transfer	49 (72.1)
Prior ICU stay	30 (44.1)
Prior pancreatitis	17 (25.0)
Chronic pancreatitis	1 (1.5)
APACHE-II score at presentation	10.9 ± .8
Any organ failure at presentation	24 (35.3)
Number (if any organ failure)	1.7 ± .2
ARDS	15 (62.5)
ARF	13 (54.2)
Shock	10 (41.7)
Gastrointestinal bleed	2 (8.3)
TPN at admission	33 (48.5)
Balthazar classification*	
Grade D	2 (3.6)
Grade E	53 (96.4)
Degree of necrosis on CT imaging†	
None	7 (14.9)
<30%	15 (31.9)
30%–50%	5 (10.6)
>50%	20 (40.5)
CT severity index	7.6 ± .3

Data are reported as number (percentage) or mean ± standard error.

APACHE-II = Acute Physiology and Chronic Health Evaluation II; ARDS = acute respiratory distress syndrome; ARF = acute renal failure; CT = computed tomography; ERCP = endoscopic retrograde cholangiopancreatography; ICU = intensive care unit; TPN = total parenteral nutrition.

*Among 55 patients.

†Among 47 patients.

Details of demographic and physiologic characteristics at the time of hospital admission are reported in Table 1. Mean age at onset of pancreatitis was 54 ± 2 years. Alcohol (38%) and gallstones (28%) comprised the most common etiologies of pancreatitis (Fig. 1). Twenty-five percent of patients had suffered prior episodes of acute pancreatitis. Forty-nine patients (72%) were transferred to our institution from an outside hospital. On admission, 49% of patients had been receiving total parenteral nutrition (TPN) and 35% suffered from one or more organ system failures. Mean predicted mortality based on admission APACHE-II score was 13%. Among 55 patients with CT imaging available for review, 53 (96%) were Balthazar class E (2 or more fluid collections and/or retroperitoneal air), while the remaining 2 patients (4%) were Balthazar class D (single peripancreatic fluid collection).

Details of the pre-necrosectomy course are displayed in Table 2. Patients most commonly underwent debridement because of infected necrosis (63%), followed by failure to thrive (19%) and sepsis syndrome (without proven infection; 13%). At the time of debridement, the mean APACHE-II score had decreased from 10.9 ± .8 (admission score) to 9.0 ± .8. Twenty-eight patients (41%) had failure of one or more organs and 22 patients (32%) required preoperative treatment in the ICU. Preoperatively, 18% of patients underwent percutaneous drainage.

Operative management

Debridement took place at a median (interquartile range [IQR]) interval of 39.5 (29 to 73) days following onset of pancreatitis. Fifteen patients (22%) underwent early necrosectomy. However, among this early debridement cohort, the majority (n = 8, 53%) of patients underwent necrosectomy in the 4th week, while fewer patients underwent necrosectomy in the 1st (n = 1), 2nd (n = 1), and 3rd (n = 5) weeks. A transmesocolic approach to the lesser sac was most frequently employed (n = 47, 70%). The mean duration of surgery was 113 ± 5 minutes (median, 109 minutes). All necrosectomies used closed suction drains and 93% packed with stuffed penrose drains. Additional information regarding operative management is displayed in Table 2.

Microbiology

Forty-three patients (63%) had infection preoperatively detected by percutaneous sampling (n = 27, 40%) and/or by identification of air in the area of pancreatic necrosis

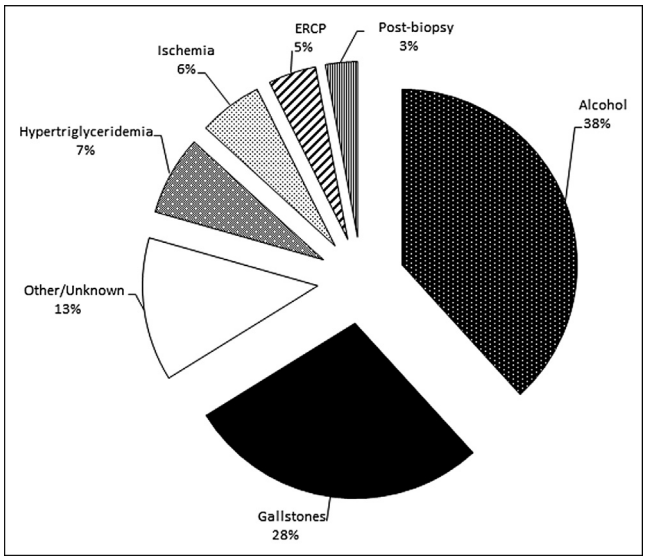

Figure 1 Etiology of pancreatitis. ERCP = endoscopic retrograde cholangiopancreatography.

Table 2 Pre-necrosectomy and operative course of 68 patients undergoing debridement for necrotizing pancreatitis

Variable	Overall cohort (n = 68)
Pre-necrosectomy course	
Median (IQR) days from onset to necrosectomy	39.5 (29–73)
Early necrosectomy	15 (22.1)
Pre–necrosectomy documented infection*	43 (63.2)
Via FNA	21 (48.8)
Via CT	16 (37.2)
Via IR drain	6 (13.9)
Preoperative percutaneous drainage	12 (17.6)
Indication for necrosectomy	
Infection	43 (63.2)
FTT	13 (19.1)
Sepsis syndrome	9 (13.2)
Biliary obstruction	2 (2.9)
Hemorrhage	1 (1.5)
APACHE-II score (preop)	9.0 ± .8
Any organ failure (preop)	28 (41.2)
Number (if any organ failure)	2.3 ± .1
ARDS	20 (71.4)
ARF	20 (71.4)
Shock	19 (67.9)
Gastrointestinal bleed	5 (17.9)
Preop ICU	22 (32.3)
TPN at the time of debridement	30 (44.1)
Operative course	
Intraoperative duration (min)	113.1 ± 5.3
Approach†	
Transmesocolic	47 (70.1)
Anterior	20 (30.3)
Retroperitoneal	3 (4.5)
Stuffed penrose placement	63 (92.7)
Positive pancreatic tissue culture (not detected preoperatively)	11 (16.2)

Data are reported as number (percentage) or mean ± standard error.

APACHE-II = Acute Physiology and Chronic Health Evaluation II; ARDS = acute respiratory distress syndrome; ARF = acute renal failure; CT = computed tomography; FNA = fine-needle aspiration; FTT = failure to thrive; ICU = intensive care unit; IQR = interquartile range; IR = interventional radiology; TPN = total parenteral nutrition.

*Sum exceeds 100% because of some patients with multiple methods of documented infection.

†Sum exceeds 100% because of multiple surgical approaches in 2 patients.

on CT scan (n = 16, 23%). Intraoperative cultures (obtained in all patients) identified infection in 11 additional patients (16%) who did not have infection diagnosed preoperatively. Among these patients with infection newly detected intraoperatively, the majority had undergone surgery for failure to thrive (7/11, 64%). Using intraoperative culture as the gold standard, the sensitivity, specificity, negative predictive value (NPV), and positive predictive value (PPV) of CT imaging were 27.5%, 88.2%, 41.7%, and 79.9%, respectively. The sensitivity, specificity, NPV, and PPV of percutaneous aspirate were 80.0%, 91.7%, 72.9%, and 94.3%, respectively. Infection was most often polymicrobial (n = 19, 28%). When monomicrobial, Gram-negative bacteria comprised the most common class of pathogen (n = 16), followed by Gram-positive bacteria (n = 15) and yeast (n = 2).

Postoperative outcomes

The median (IQR) total length of hospital stay was 21.5 (14 to 43) days. The median (IQR) postoperative length of stay was 14.5 (11 to 31) days. Postoperatively, 44 patients required ICU admission (65%), with a median (IQR) length of ICU stay of 6 (2 to 15) days. Forty patients (61%) received a period of TPN postoperatively. Reintervention (2nd operation or interventional radiology percutaneous drain placement) occurred for 36 patients (62%). Specifically, 28 patients (41%) had percutaneous drains placed. Ten patients (15%) required one or more operations for indications including persistent symptoms, intra-abdominal bleeding, persistent pancreatic fistula, wound dehiscence, and enterocutaneous fistula. These patients underwent a 2nd operation at a median (IQR) of 30.5 (7 to 274.5) days postoperatively. Twenty-nine patients required readmission for further therapy related to necrotizing pancreatitis. First readmission occurred at a median (IQR) of 13 (8 to 50) days following discharge (Fig. 2).

Forty-nine (74%) patients developed pancreatic fistulae. All fistulae but one closed spontaneously. The one patient with a persistent fistula required surgical intervention 23 months after her initial debridement for a persistently recurrent pancreaticocutaneous fistula because of a disconnected distal pancreatic remnant. Spontaneous closure occurred at a median (IQR) of 73 (35 to 136) days postoperatively (Fig. 3). Endocrine and exocrine deficiency developed postoperatively in 21% (n = 14) and 10% (n = 7) of patients, respectively. With regard to postoperative surgical complications, 6 patients (9%) developed enterocutaneous fistulae and 6 patients (9%) developed incisional hernias. Among the 6 patients with enterocutaneous fistulae, 5

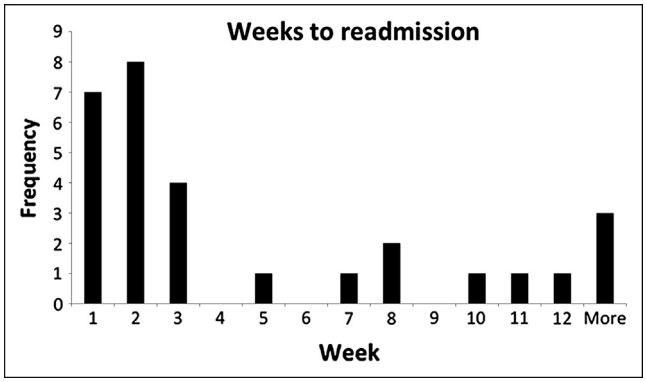

Figure 2 Distribution of interval between discharge and first readmission among 28 patients who were readmitted.

Table 3 Postoperative course of 68 patients following debridement for necrotizing pancreatitis

Variable	Overall cohort (n = 68)
Mortality	6 (8.8)
Transfusion	42 (61.8)
Intra-abdominal bleed	12 (17.7)
Wound infection	9 (13.2)
Enterocutaneous fistula	6 (8.8)
Any de novo organ failure	17 (25.0)
Number (if any organ failure)	1.3 ± .1
Shock	9 (52.9)
Gastrointestinal bleed	6 (35.3)
ARDS	5 (29.4)
ARF	3 (17.7)
Postop TPN	40 (60.6)
Postop ICU	44 (64.7)
Median (IQR) ICU days	6 (2–15)
Median (IQR) total hospital days	21.5 (14–43)
Median (IQR) postop hospital days	14.5 (11–31)
Pancreatic fistula	49 (74.2)
Median (IQR) days to closure	73 (35–136)
Endocrine insufficiency	14 (20.6)
Exocrine insufficiency	7 (10.3)
Hernia	6 (8.8)
Readmission	28 (41.2)
Median (IQR) days to readmission	13 (8–50)
Reintervention	36 (62.1)
Second operation	10 (14.7)
Median (IQR) days to reoperation	57.5 (21–583)
Percutaneous drain	28 (41.2)
Number	2.5 ± .4

Data are reported as number (percentage), mean ± standard error, or median (interquartile range).

ARDS = acute respiratory distress syndrome; ARF = acute renal failure; ICU = intensive care unit; IQR = interquartile range; TPN = total parenteral nutrition.

patients were managed nonoperatively. One patient (17%) expired from sepsis following attempted operative repair of a persistent gastrocutaneous fistula 9 months after discharge from her initial hospitalization for pancreatitis. The long-term mortality rate was 66% (4/6) among patients who developed enterocutaneous fistulae because of sepsis in all cases. Further details of the postoperative course are reported in Table 3.

Seventeen patients suffered new onset organ failure (25.0%) following debridement. Among patients with preoperative percutaneous drain placement, 25% (3/12) suffered de novo organ failure, while among patients without preoperative percutaneous drain placement, 25% (14/56) suffered de novo organ failure ($P = .99$). New postoperative organ failure after debridement was associated with a number of factors (Table 4): postoperative pancreatitis as the etiology of the pancreatitis ($P < .01$), ICU admission during the hospitalization ($P < .01$) or at the time of debridement ($P < .01$), higher APACHE-II score at presentation ($P < .01$) or at the time of debridement ($P < .01$), and retroperitoneal approach ($P = .01$).

The in-hospital mortality rate was 8.8% ($n = 6$). Death occurred at a median (IQR) of 46 (22 to 137.5) days. Factors significantly associated with mortality are reported in Table 4. Upon admission, nonsurvivors were more likely than survivors to be older ($P = .02$) and have higher APACHE-II scores ($P = .03$). Additionally, nonsurvivors were more likely to have had a preoperative ICU admission ($P = .01$). At the time of debridement, nonsurvivors were more likely to have higher APACHE-II scores ($P < .01$). Finally, nonsurvivors were more likely to have suffered new postoperative organ failure compared with survivors ($P = .03$). There was a nonsignificant trend toward association between mortality and the following variables: organ failure at admission (nonsurvivors vs survivors; 67%, $n = 4$ vs 32%, $n = 20$, $P = .17$), organ failure at the time of debridement (83%, $n = 5$ vs 37%, $n = 23$, $P = .07$), and postoperative ICU admission (100%, $n = 6$ vs 61%, $n = 38$, $P = .08$).

Comments

Although a number of retrospective series of pancreatic debridement from around the world have been described over the preceding decades, this series differs for several reasons. We report on one of the few modern series that rely primarily on open surgical debridement as the foundation of intervention for necrotizing pancreatitis. As minimally invasive percutaneous, endoscopic, and laparoscopic techniques have proliferated in recent years, data on modern outcomes with open surgical debridement have become scant. Furthermore, little direct comparison between approaches exists. Studies comparing open with minimally invasive techniques have necessarily selected patients amenable to minimally invasive approaches, which ultimately results in the analysis of a specific subset of patients with necrotizing pancreatitis. As critical care, nutrition, and other adjunctive care continue to improve, series of open debridements published years ago may suffer by comparison with more modern series using minimally invasive

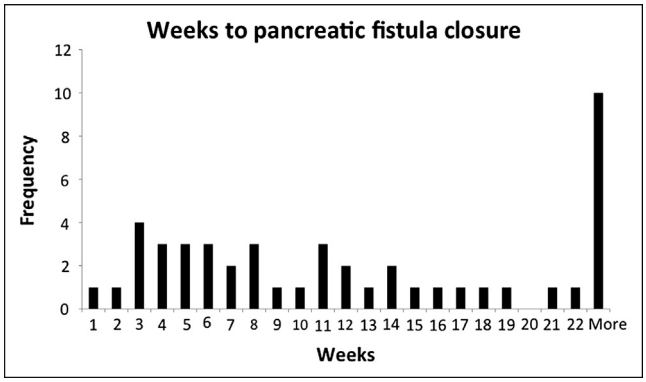

Figure 3 Distribution of spontaneous closure time among 49 patients with postoperative pancreatic fistulas.

Table 4 Factors significantly associated with postoperative organ failure and in-hospital mortality

Variable	Organ failure (n = 17)	No organ failure (n = 51)	P value
Etiology: postoperative ischemia	4 (23.5)	0 (.0)	<.01
ICU during prior hospitalization	14 (82.3)	16 (31.3)	<.01
Preoperative ICU	12 (70.6)	10 (19.6)	<.01
Retroperitoneal approach	3 (17.5)	0 (.0)	.01
APACHE-II score			
At presentation	15.5 ± 1.8	9.4 ± .9	<.01
At the time of debridement	15.8 ± 1.9	6.7 ± .7	<.01
Variable	**Nonsurvivors (n = 6)**	**Survivors (n = 62)**	**P value**
Age at onset (years)	64.7 ± 3.4	53.2 ± 1.9	.02
APACHE-II score at presentation	18.2 ± 3.6	10.2 ± .8	.03
APACHE-II score at debridement	15.0 ± 2.5	8.4 ± .9	<.01
Preoperative ICU admission	17 (27)	5 (83)	.01
Postoperative organ failure	13 (21)	4 (67)	.03

Data are reported as number (percentage) or mean ± standard error.
APACHE-II = Acute Physiology and Chronic Health Evaluation II; ICU = intensive care unit.

techniques. Given its size, this series was compiled over a relatively short period of time (2006 to 2009); thus minimal changes were likely to have occurred in adjunctive medical or interventional management. For these reasons, we believe that this series provides a unique picture of modern outcomes with open surgical debridement.

Our main finding is a relatively low in-hospital mortality of 8.8% despite severe disease by prognostic indices on admission. Historically, mortality ranged from 13% to 26% (median 19%) among large published series of open pancreatic necrosectomy.[13] A number of factors complicate comparison of mortality rates between studies. Timing of intervention, clinical characteristics of patients (such as age, APACHE-II score, and prevalence of infected necrosis), and reporting methods often differ, with some series reporting 30-day outcomes, while others report in-hospital or longer term outcomes. The largest published series of open necrosectomies by Gotzinger et al[14] from 2003 describes a 46% in-hospital mortality rate following surgery within 3 weeks of diagnosis and a 25% in-hospital mortality rate following surgery after 3 weeks or more from diagnosis. In a more recent 2010 randomized controlled trial by van Santvoort et al,[9] the mortality rate (with 3-month post-discharge follow-up) among 45 patients undergoing open necrosectomy was 19%. Admission APACHE-II scores and the incidence of infected necrosis were higher in both of these studies than in the present analysis, possibly contributing to the higher mortality rates. Nonetheless, overall severity of illness in our study is in line with a number of other series reporting higher mortality rates.[15–17] Additionally, many patients in our series were transferred to our institution after the critical illness phase of their pancreatitis, but when they were believed to be in need of debridement. Thus, the reported admission APACHE-II scores are likely lower than they would have been had the patients been admitted directly to our institution. The American College of Surgeons National Surgical Quality Improvement Program reported a 6.8% 30-day mortality rate nationwide for pancreatic necrosectomy significantly lower than those previously described, but unfortunately lacking information beyond the 1-month mark.[18] At our institution, open debridement has been associated with similarly low mortality rates ranging from 6.2% to 11.4%.[8,12] The in-hospital mortality rate of 8.8% reported in this study falls within this range and represents a useful benchmark for newly developing techniques.

In our analysis, factors associated with mortality included older age, increasing admission or preoperative APACHE-II score, preoperative ICU admission, and postoperative organ failure. These findings are congruent with a prior series from our institution by Rodriguez et al,[8] in which organ failure and longer postoperative ICU stay as well as female sex and early debridement correlated with increased mortality. Similarly, the aforementioned study by Gotzinger et al[14] identified increasing APACHE-II score, early debridement, and incomplete surgical removal of necrotic tissue as associated with mortality. These and other studies have suggested that late debridement is optimal;[8,16,19–21] however, our analysis was not specifically designed to assess this factor and did not find an association between timing of debridement and mortality. The small number of patients undergoing early debridement and the low event rate for mortality may have underpowered any true underlying association between timing of debridement and mortality. Additionally, the majority of the patients who underwent early debridement (before 28 days) did so in the 4th week, which would likely minimize any adverse effects of early debridement.

Among patients afflicted with necrotizing pancreatitis, 30% develop infection of the necrotic tissue.[3] Many consider infection the sole indication for necrosectomy; however, infection remains difficult to diagnose preoperatively. In this study, percutaneous aspiration had a sensitivity and specificity of 80% and 92%, respectively, with a PPV and NPV of 94% and 73%, respectively. Several studies have assessed methods of preoperative testing for infected

pancreatic or peripancreatic necrosis. In a 1990 study of 15 patients who underwent open debridement for necrotizing pancreatitis, Banks et al[22] reported a sensitivity and specificity of 100% for CT-guided fine-needle aspiration (FNA). In a review of 5 small studies of CT- or ultrasound-guided FNA for detecting infection in the setting of acute pancreatitis, sensitivity ranged from 90% to 100% and specificity ranged from 96% to 100%, again using intraoperative bacteriology as the gold standard.[23] Rau et al[23] prospectively evaluated FNA testing for infection among patients with necrotizing pancreatitis and found a specificity and sensitivity of 88% and 90%, respectively. Because of the imperfect performance of preoperative tests for infection, some groups opt not to employ FNA when considering the need for surgery.[24] A recent evidence-based consensus conference declared that there are relatively few indications for purely diagnostic FNA.[6] Our data support this statement and reinforce the practice of undertaking intervention when there is high clinical suspicion for infection.

For decades, open surgical debridement remained the standard of care in the treatment of pancreatic necrosis. More recently, less invasive approaches have begun to replace open surgical debridement, including percutaneous drainage alone, VARD, and transgastric endoscopic debridement.[6] A number of case series report excellent results using these techniques, although many are subject to selection bias.[25–27] The largest randomized trial to date comparing a "step-up" approach with primary open debridement resulted in lower rates of new onset organ failure, diabetes, and hernia in the "step-up" group, although mortality did not significantly differ between groups.[9] Another recent randomized controlled trial of 20 patients with infected pancreatic necrosis revealed decreased mortality and complication rates with transgastric endoscopic debridement compared with open surgical debridement.[28] However, the small size and the exorbitant mortality rate (40%) in the surgical group limit the generalizability of these results.[28] Finally, a prospective nonrandomized study demonstrated the efficacy of VARD following percutaneous drain placement for infected pancreatic walled-off necrosis among 31 patients, with 2.5% in-hospital 30-day mortality.[29] These studies comprise a welcome move toward evidence-based evaluation of therapy for infected pancreatic necrosis, but have limitations. Only patients with necrosis anatomically amenable to minimally invasive techniques (a variable percentage of those evaluated for inclusion) were entered into these trials. Second, they report relatively high open surgical mortality rates. Accordingly, the possibility remains that open surgery performed with a lower mortality rate, along the lines of that reported here, may offer equivalent or better outcomes. The minimally invasive techniques described above are, no doubt, powerful tools in the management of necrotizing pancreatitis and, indeed, we used percutaneous drainage both preoperatively (18%) and postoperatively (41%). However, the low mortality rate achievable in the modern era using open surgical debridement supports an ongoing role for open surgery.

There were several limitations to our analysis, some of which have been alluded to above. First, this analysis included only patients who underwent debridement. This does not allow consideration of other patients with severe necrotizing pancreatitis, or even infected pancreatic necrosis, who may not have undergone surgery. Such a global view, as recently presented by van Santvoort et al,[30] could have provided a more complete picture of the role of surgery and other interventions in the management of pancreatitis. Although our treatment strategy was predicated primarily on open surgical debridement, a significant number of patients underwent preoperative percutaneous drainage. One could argue that this in essence constitutes a "step up" approach and that our results, including the relatively low mortality, may be attributable to the incorporation of minimally invasive techniques. This is true to some degree, although during the study period we did not perform systematic preoperative percutaneous or endoscopic drainage (a tenet of the "step-up" approach). Rather, we used these techniques as a "bridge" to surgery among patients with proven or suspected infected necrosis and worsening clinical status, in whom we sought to delay surgery and avoid early debridement. Similarly, we did not perform multiple minimally invasive procedures in an effort to obviate surgery, but followed all temporizing drainage procedures with debridement. Interestingly, the incidence of new onset organ failure, the reduction of which appears to be one of the main advantages of a "step-up" approach, was not different between the patients who underwent preoperative percutaneous drainage and those who did not in this study. Second, as a retrospective analysis, reporting of outcomes was incomplete. It is unlikely that this incomplete reporting differentially affected any one subset of patients. However, to mitigate potential bias, we limited the study period to a 4-year window during which clinical care was most likely to be otherwise consistent. Late follow-up for significant complications such as hernia was sporadic. We likely underestimate this complication, which remains one disadvantage of open surgery compared with minimally invasive techniques.

In summary, open necrosectomy was associated with a relatively low mortality rate, which compares favorably with many series utilizing minimally invasive approaches. Older age, increasing admission or preoperative APACHE-II score, preoperative ICU, and postoperative organ failure were significantly associated with mortality. Further research is warranted to identify the best treatment strategy for patients with necrotizing pancreatitis, but this series may serve as an up to date reference for outcomes with open necrosectomy.

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